1-G-31

MODEL 2710 - 2720
GALVO-DRIVE AMPLIFIERS

DANA

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Section 1

General Description

1.1 INTRODUCTION

Dana Models 2710 and 2720 Galvo-Drive Amplifiers (Figure 1.1) are universal instruments for driving wideband galvanometers and other analog recording devices.

Flexibility of the amplifiers allows the instrumentation engineer to standardize on a comparatively small number of galvanometer types. Variable front-panel gain settings permit the use of both high-level and medium-level transducers in a single, standardized data-gathering network. Input signals may range from thermocouples and strain gages to the high-level output of tape decks, discriminators and potientometric transducers.

Both models are equipped with a "zero" position on the gain control which disconnects the amplifier from the source and shorts the input leads. Model 2720 has an additional front-panel control by which the zero point can be moved to the right or left across the full scale range. This greatly simplifies the setup procedure, since only a coarse mechanical adjustment of the horizontal spot position is required.

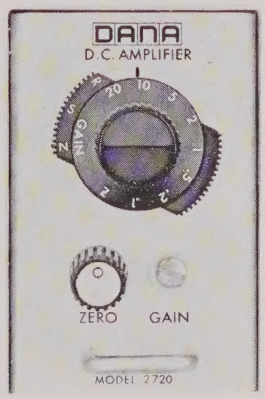


Figure 1.1a - Model 2720

Both amplifier models include terminals for installing resistors to match the amplifier and cable resistance with the required galvanometer damping resistance. The output impedance of the amplifier itself is both low and stable across a broad frequency range.

The amplifiers are three-terminal devices, having a high degree of isolation between any terminal and the amplifier case or power ground. The galvanometer is protected by voltage and current limiting of the amplifier output. The amplifier is short-circuit proof and can withstand up to 20 volts across the input leads. Full scale output is $\pm$ 10 volts.

Up to eight amplifiers may be mounted in a single rack enclosure supplied by Dana. The enclosures are 5-1/4 inches high, with printed-circuit connectors provided for each amplifier. Dust covers and input-output cables are also available for individual amplifiers.

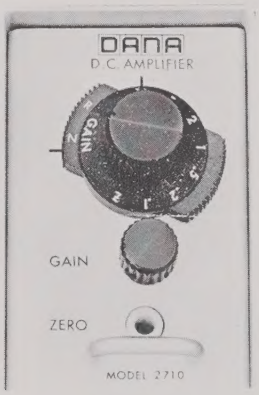


Figure 1.1b - Model 2710

1.2 SPECIFICATIONS

	Model 2710	Model 2720
Output		
Full-Scale	± 10 volts, 100 ma	± 10 volts, 100 ma
Overrange (nominal)	20%	20%
Impedance		
DC	0.1 ohm	0.1 ohm
DC to 2 Kh	0 ohm	1 ohm
DC to 10 Kh	5 ohms	5 ohms
Capacitive Load (without instability)	1 µfd	1 µfd
Short Circuit Protection	Output limited to ± 13 volts (peak), 150 ma	Output limited to ± 13 volts (peak), 35 to 150 ma
Reversing Switch	Reverses Output Leads	Reverses or Shorts Output Leads
Frequency Response (Source resistance to 1K)		
DC to 2 Kh	± 1% at	± 1% at
DC to 10	± 2% full	± 2% full
DC to 20 Kh	± 5% output	± 5% output
DC to 50 Kh	-3db at 10% Full Scale	-3db at 10% Full Scale
Phase Shift - DC to 400 h	1° (max)	1° (max)
Distortion - at Full Output	0.1% (max) at 1 Kh	0.05% (max) at 1 Kh
Linearity at Full Output		
DC	.05%	0.02%
AC to 3 Kh	0.2%	0.1%
Gain		
Fixed Steps	Zero*, .1, .2, .5, 1, 2, 5, 10	Zero**, .1, .2, .5, 1, 2, 5, 10, 20
Accuracy	± 0.5%	± 0.5%
	*Zero position disconnects source; shorts amplifier input to Common.	**Zero position shorts amplifier input to Common; 100K across source.

1.2 SPECIFICATIONS (continued)

	Model 2710	Model 2720
Stability	± .1%	± 0.1%
Vernier	Variable to 2.5 x Fixed Step	Variable to 2.5 x Fixed Step
Noise (Referred to Input)	15 μv (rms) at Gain of 10	25 μv (rms)
Step Function Settling Time	100 μsec. to .5% of F/S	50 μsec. to .5% of F/S
Overload Recovery (From 500%)	500 μsec. to .5% of F/S	200 μsec. to .5% of F/S
Zero Drift (up to 1 Kh Source; after 30-minute warmup)		
Constant Temp., 40hrs	± 0.02% of F/S	± 0.02% of Full Scale ± 0.1% of zero-offset
Per ^{o}C	± 0.01% of F/S	± 0.03% of Full Scale ± 0.05% of zero-offset
Zero Control	± 0.5% of F/S	± 100% of Full Scale
Input Impedance		
Gains of 1 and above	2 megohms	100 Kilohms
Gains below 1	100 Kilohms	100 Kilohms
Fault Protection	Up to 20 volts normal mode will cause no damage; up to 250 volts to case or power ground will cause no damage.	Same
Isolation (any terminal to case or power ground)	10^{8} ohms in parallel with less than 500 pf	10^{8} ohms in parallel with less than 500 pf
Power Requirements	105-125 volts, 50-400 hz, 5 watts	105-125 volts, 50-400 hz, 5 watts
Units per Dana 3008 Enclosure	8	8
Weight	4 lbs.	9 lbs.

Section 2

Installation And Initial Checkout

2.1 UNPACKING AND INSPECTION

The Dana Galvo-Drive Amplifier is shipped in a special reusable shipping package, designed to protect the instrument from excessive shock and vibration. Examine the package for signs of external damage before removing the unit. If external damage is present, notify the carrier before proceeding. Next, examine the outside of the amplifier for any evidence of damage due to excessive shock, vibration, water leakage, etc.

If the unit appears in perfect condition, proceed with the installation. However, if there is any apparent damage, communicate with the carrier for instructions.

2.2 POWER REQUIREMENTS

Dana Amplifiers, manufactured for domestic use, operate on 115 volts (± 10 volts) 50 to 400 Hz. Units manufactured for export operate on 210 to 250 volts, 50 to 400 Hz. Power required is 5 watts.

Note

If the Amplifier has been stored for a prolonged period, (5 or 6 months) without use, it is recomended that it be operated with a variable transformer, such as a Variac, at one-half line voltage for about two hours before gradually applying full power. This is done to "reform" the electrolytic capacitors in the amplifier and reduce the chance of capacitor failure.

2.3 INPUT/OUTPUT CONNECTIONS

2.3.1 General

Inputs and outputs to the amplifier are through a 15-pin printed circuit connector at the rear of the amplifier. External connections are brought in through a mating connector. When Dana enclosures are used, the mating connector for each amplifier is mounted on the inside back panel of the enclosure; each amplifier plugs

into its corresponding connector. When amplifiers are used singly, a cord set is normally used. The cord set includes the mating connector, power cord, and clip leads for input/output signal connections.

When the 3008-1 enclosure is used, external connections are made directly to the solder side of the enclosure mounted connector for each amplifier. Access to connectors is gained by removing the plate at the rear of the enclosure. External leads are routed up from the bottom side of the rear of the enclosure.

In 3008-2 enclosures, conventional cable connectors are mounted on the rear panel. Connections are made by wiring to the mating connector. All pin connections are identified in Figure 2.1 and in the following table.

	TERMINAL	WITHOUT PADDING RESISTORS	WITH PADDING RESISTORS
Key	A	AC POWER GROUND	AC POWER GROUND
	B	AC POWER (HIGH)	AC POWER (HIGH)
	C	AC POWER (LOW)	AC POWER (LOW)
	D	AC POWER GROUND	AC POWER GROUND
Key	E	AC POWER GROUND	AC POWER GROUND
	F	OUTPUT LOW SIDE (IN NORMAL)	OUTPUT LOW SIDE (IN NORMAL)
	H	OUTPUT HIGH SIDE (IN NORMAL)	PADDED OUTPUT (HIGH SIDE)
	J	OUTPUT SHIELD (AMPLIFIER COMMON)	OUTPUT SHIELD (AMPLIFIER COMMON)
	K	NOT USED	NON-PADDED OUTPUT
	L	COMMON TO PIN N	COMMON TO PIN N
	M	COMMON TO PIN N	COMMON TO PIN N
	N	INPUT LOW SIDE	INPUT LOW SIDE
	P	INPUT HIGH SIDE	INPUT HIGH SIDE
	R	COMMON TO PIN N	COMMON TO PIN N
	S	COMMON TO PIN N	COMMON TO PIN N

For permanent installations, low thermal solder (70% cadmium, 30% tin) must be used for all input connections. For temporary or test setups, screw terminals or clips having low resistance may be used, taking suitable care to minimum thermal emf's (a few microvolts can be significant on high gain ranges).

2.3.2 Power

When the amplifier is to be operated within a 3008-1 enclosure — or if it is to be operated singly using a cord set, the power circuit is prewired and a three-wire line cord is supplied.

When a 3008-2 enclosure is used, power leads must be wired to the mating connector of the AC Power Connector — located on the rear panel of the enclosure. A three-wire cord must be used. The ground wire connects to the internal power supply shields.

CAUTION

If the amplifier is to be operated on the bench, make certain that the 15-pin amplifier connector is properly keyed. Reversal of the connections may result in damage to the amplifier.

2.3.3 Input

Single-conductor shielded cable should be used for input leads. The input is applied to terminals P and N at the amplifier connector or to the same terminals on enclosure 3008-1, if that enclosure is used. The center conductor is connected to P and the shield to N. If enclosure 3008-2 is used, the center conductor is connected to pin C and the shield to pin A of the input connector.

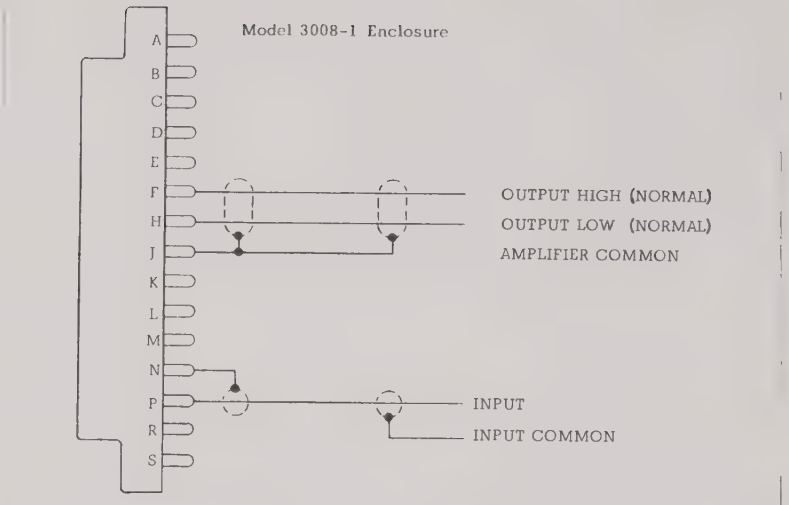
2.3.4 Output

The output is normally taken from the amplifier, or 3008-1 enclosure, terminals F, H, and J. When padding resistors are used (Section 2.3.5) a direct output, bypassing the resistors, may be obtained at pin K.

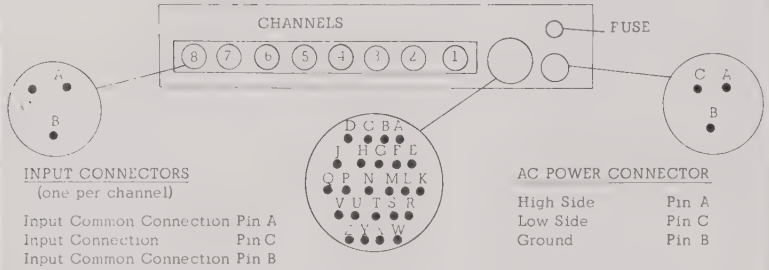
When the output reversing switch is in NORMAL, pin H or K is output high side and pin F is output low side (connects to input low side). When the output reversing switch is in REVERSE, pin F is output high side and pin H or K is output low side (connects to input low side). Pin J connects to amplifier common (input low side) regardless of the position of the reversing switch.

It is recommended that the output cable be two-conductor shielded. The inner conductors should be connected to pins H or K and F at the amplifier output terminals and to the load at the load end of the cable. The shield should be connected to pin J at the amplifier terminals and should not be terminated at the load end of the cable.

When enclosure 3008-2 is used, the output is taken from the output connector at pins designated in Figure 2.1. The pins are reversed by the reversing switch on the amplifier.



Model 3008-2 Enclosure



INPUT CONNECTORS
(one per channel)

Input Common Connection Pin A
Input Connection Pin C
Input Common Connection Pin B

AC POWER CONNECTOR

High Side	Pin A
Low Side	Pin C
Ground	Pin B

Output Connections
Model 3008-2

Channel	Output High (Normal)	Output Low (Normal)	Shield
1	E	F	A
2	B	C	G
3	H	J	D
4	K	L	R
5	M	N	T
6	P	Q	V
7	W	X	S
8	Y	Z	U

	Mating Connector and Clamps	Dana Part Number
INPUT	3106 A-10 S1-3S A105-A115	601561
(3 sets required)	3057-4A-A105 w/Bush	601474
OUTPUT	3106 A-24-28P-639	601563
(1 set required)	3057-16A-639 w/Bush	601564
AC POWER	3106 B-14S-7S-639	601640
(1 set required)	3057-6A-639 w/Bush	601639

Figure 2.1 - Enclosure Wiring

2.3.5 Padding Resistors

If a low resistance load, such as a recording galvanometer with a typical 25-ohm resistance is to be driven, series resistance can be added so that full scale of the recording instrument corresponds with amplifier full scale. This increases the accuracy of the instrumentation system and also serves to protect the recording instrument from damaging overload. Should the load require a particular driving resistance, such as an external damping resistance, a simple two-resistor network is needed between the amplifier and the load (see Figure 2.2).

Padding resistors in series with the galvanometer are connected across the R_A pad; resistors in parallel with the galvanometer are connected across the R_B pad.

When padding resistors are used, the high output lead normally soldered to the amplifier side of terminal H should be disconnected and soldered to eyelet T (see Figure 4.2). Location of the padding resistors is shown in Figure 2.3.

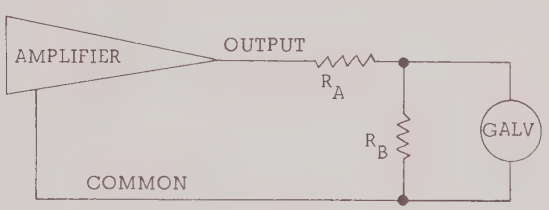


Figure 2.2 - Two-Resistor Network for Damping Galvanometer

Values for R_A and R_B are defined by:

$$R_A = \frac{10V}{I_{FS}\left(1 + \frac{R_g}{R_d}\right)}$$

and

$$R_B = \frac{R_A \; R_d}{R_A - R_d}$$

Where:

R_d = Required External Damping Resistance

R_g = Galvanometer Resistance

I_{FS} = Galvanometer Full Scale Current

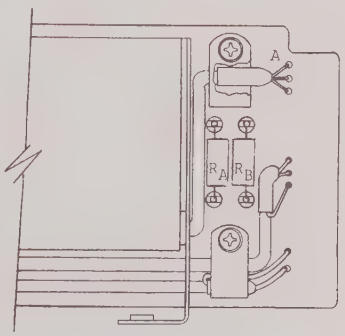


Figure 2.3
Padding Resistors - Physical Location

2.4 CHECKOUT PROCEDURE

The amplifier is accurately adjusted and carefully inspected at the factory. The following tests check basic characteristics of the amplifier to verify proper operation upon delivery. The type of damage that can be expected in shipment tends to produce gross malfunctions rather than minor changes in sensitive characteristics.

Only three items of test equipment are required to perform initial checkout of the amplifier:

Audio Oscillator
Voltage Divider/Attenuator
Oscilloscope

Standard laboratory-type instruments from any manufacturer may be used.

2.4.1 Gain Checkout

1. Connect the common or ground terminals of each item of test equipment to a single point and to the amplifier output common (F). Connect this point to ground. Make all measurements relative to this point (see Figure 2.4).

2. Set voltage divider to minimum output — zero, if possible.

3. Apply power to amplifier. Observe amplifier output on oscilloscope. It should be within a few millivolts of ground and change only very slightly as the amplifier GAIN switch is rotated.

4. Set the vernier gain adjustment fully counterclockwise.

5. Set the GAIN selector switch to the maximum gain position.

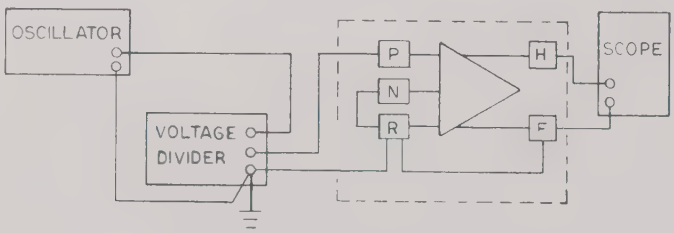


Figure 2.4 - Gain Test Setup

6. Remove scope lead from amplifier output and connect scope to the oscillator output. Adjust oscillator for 20 volts, peak to peak, at 100 Hz.

7. Set voltage divider to the reciprocal of the maximum gain setting, 1K. (For example, at maximum gain of 20, set divider to .05; at gain of 10, set divider to .1.)

8. Return the scope to the amplifier output, pin H. The scope should now indicate approximately the same value, 20 volts peak to peak, observed at the oscillator output. (The term "approximately" is used because of the limited capability of an oscilloscope to compare two magnitudes accurately.)

9. Verify that there is no obvious noise or other unexplained distortions on the oscilloscope trace.

2.4.2 Frequency Response Checkout

1. Use test setup exactly as connected for Gain checkout. Set amplifier GAIN control at maximum; vernier adjustment to minimum. Connect scope to oscillator output; set oscillator frequency to 20 kHz.

2. Set oscillator output at 20 volts, peak to peak (on scope).

3. Remove scope lead from oscillator and connect to amplifier output pin H. Adjust voltage divider for amplifier output amplitude equal to that observed in Step 2.

4. Compare voltage divider setting with zero — or minimum output position. The difference should be no more than approximately 5%.

Section 3

Operation

3.1 CONTROLS

The function of each control is described in the following table:

CONTROL	FUNCTION	
	MODEL 2710	MODEL 2720
GAIN Selector	Selects gain at fixed steps from .1 to 10; zero (Z) position shorts input leads.	Selects gain at fixed steps from .1 to 20; zero (Z) position shorts input leads.
Output Control	Normal output on N; Reversed output on R.	Normal output on N; Reversed output on R; Output leads shorted on S.
GAIN Adjustment	This control is a vernier gain adjustment. In the extreme counterclockwise position, gain is equal to the fixed step (set by Gain Selector). As the control is turned clockwise, the gain increases up to 2.5 times the fixed step at the extreme clockwise position. In this position, the gain "overlaps" the next higher fixed step.	Function same as in Model 2710, except that control is a screwdriver adjustment.
ZERO Adjustment	Screwdriver adjustment used to set amplifier output to zero with input shorted (Gain Selector to Z). Should be adjusted after warmup period.	Control used to electrically adjust the zero point of the galvanometer trace by full scale magnitude in either direction. If it is desirable to make this adjustment with input shorted, place Gain selector to "Z".

3.2 OPERATING ADJUSTMENTS

In addition to the gain and zero adjustments described in the preceding table, the output current limit adjustment may be required for particular applications.

3.2.1 Output Current Limit Adjustment

Although the output short circuit current is set at the factory for ±150ma, it may be desirable to limit the output current to a lesser value to afford galvanometer protection. Potentiometers R17 and R18, located on the printed circuit board (Part 400476), vary the output short circuit current from 35ma to 150ma. A voltage limit at the output of ±13V DC or peak AC provides an additional degree of protection to the load.

3.2.2 Galvo Mechanical Zero Adjustment (Model 2720 Only)

The Output Control switch (N-S-R), when in the short (S) position, effectively shorts out the galvanometer input leads and allows the zero point of the galvanometer to be shifted to the desired position. This is a coarse adjustment and is usually followed by a finer electrical adjustment.

Section 4

Theory Of Operation

4.1 INTRODUCTION

Dana Galvo-Drive Amplifiers are solid-state, non-inverting DC amplifiers with integral power supply. Direct coupling is used throughout; no modulators — mechanical or otherwise — are used. The amplifiers are wideband devices having a small signal 3db point of greater than 50kHz.

Since Models 2710 and 2720 are similar, descriptions generally pertain to both models unless otherwise noted. Each unit is a three-terminal floating amplifier (Figure 4.1). The low sides of the input and output are internally tied to amplifier common. Amplifier circuitry, including amplifier common, is isolated from the case and from power ground. This allows the amplifier to be operated in a "floating" configuration when either the source or load is ungrounded.

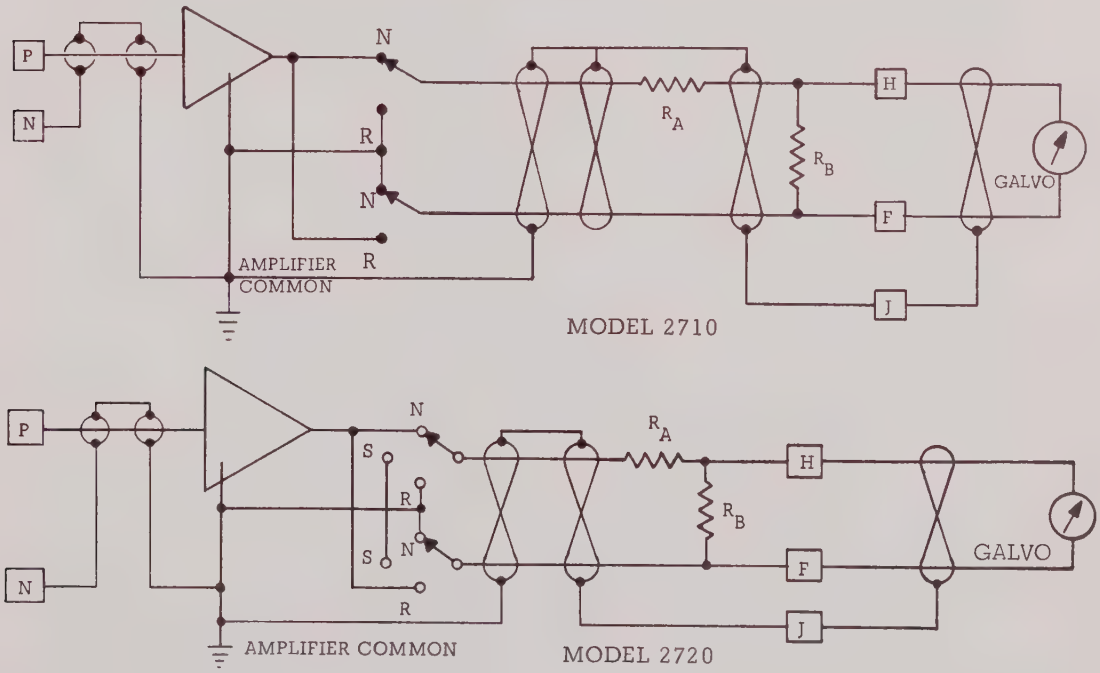


Figure 4.1 - Dana Galvo-Drive Amplifiers — Block Diagram

4.2 AMPLIFIER & POWER SUPPLY

Generally, the amplifier and power supply portion of the instrument is the same in both models. Reference should be made to the schematics in Section 6: Drawing 430267 for Model 2710 and Drawing 430296 for Model 2720.

The basic open loop amplifier has a differential input and a single-ended output The power supply consists of two isolated sections. One supplies ±20 volts and is a zener diode series regulated supply. The other section supplies ±100ma and is a full-wave bridge rectifier with capacitive filters. In Model 2720, two additional zener diodes across the 20-volt output supply ±5 volts to the ZERO adjustment potentiometer.

The first stage (Q11A, Q11B, Q12) is a balanced differential amplifier and current generator which amplifies the difference signal at its bases and feeds the second stage differential amplifier (Q10A, Q10V). An emitter follower (Q9) off the collector of Q10A provides current gain to the driver stage (Q7, Q8) and minor loop roll-off (R25, C14). R27 and C15 roll off forward gain in the minor loop, while R31 and C17 preserve minor loop roll off symmetry. A class AB output stage (Q3, Q4, Q5, Q6) is employed to eliminate crossover distortion. The output roll off capacitor (C8) allows an output loop to be closed through C10. R37 is a factory selected resistor which supplies base current to Q11A. R17 and R18 adjust the + and - short circuit current limits, while CR22 and CR23 limit the output voltage swing to ±13 volts. R38 allows the gain vernier zero shift to be set to zero.

Terminals are provided on the amplifier for the installation of series and parallel padding resistors (see Section 2.3.5) between the amplifier and output terminals H and F. The electrical location of the terminals is shown in Figure 4.2. When the padding resistors are used, the high output lead normally connected to the amplifier side of pin H is removed and connected to eyelet T. R_A is then in series with the output to pin H and R_B is between pin H and common (pin F). With the padding resistors installed, the non-padded output is available at pin K.

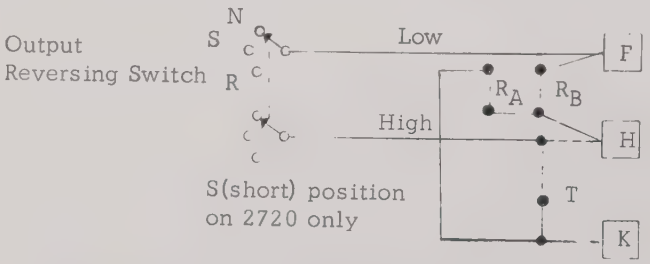


Figure 4.2 - Padding Resistance

4.3 SWITCH ASSEMBLY — Model 2710 (Refer to Drawing 430267)

In Model 2710, the switch assembly section contains the output reversing switch, gain selector switch, vernier gain control, and zero adjustment.

Switch deck S2A is in the feedback circuit. It switches resistors into the circuit to select amplifier gain. Feedback gains of 10, 5, 2, and 1 are provided by this switch. Gains of less than 1 (.5, .2, and .1) are provided by a ten-to-one input divider controlled by switch deck S2D. S2C switches RC networks into the circuit to maintain constant loop gain in each gain position.

In ZERO position, the input is disconnected from the amplifier and the amplifier input is shorted to common. This is accomplished by switch deck S2B.

Potentiometer R39, in series with the selected feedback resistance (S2A) provides continuous variable gain between the fixed steps. R38, in the first stage of the amplifier, shifts output zero $\pm$.5% of full-scale output.

The single-ended amplifier output and amplifier common are routed to output pins F and H through a reversing switch. In NORMAL position, amplifier output is on pin H and common on F. In REVERSE, amplifier output is on pin F and common on pin H. This is shown in Figure 4.1.

4.4 SWITCH ASSEMBLY — MODEL 2720 (Refer to Drawing 430296)

In Model 2720, the switch section contains the attenuator and gain resistors, output switch, gain selector switch, vernier gain control and full scale zero adjustment.

R43 is the gain vernier potentiometer. In the full counterclockwise position, switch S3 is activated connecting R44 to R42. As R43 is turned clockwise, S3 switches from R42 to R43 and the resistance of R43 increases. R40, R42, and R44 are the feedback gain resistors. They provide a feedback gain of 30 when S3 is in the R42 position. As the gain vernier control R43 is rotated clockwise, gain is increased up to 2.5 times.

Attenuator resistors (R45 through R53) and gain selector switch (S1) provide a constant input impedance of 100 kilohms and attenuation ratios of 1/300 to 2/3. These ratios, times the closed loop fixed gain of 30, yield overall gains of .1 to 20. When the gain selector switch is in the zero position, the 100 kilohm input resistance remains across the input terminals of the amplifier and the input to the potentiometric amplifier is shorted to input common. This allows the output of the amplifier to be adjusted anywhere from +10 volts to -10 volts, independent of the gain switch or vernier gain control, by means of the zero potentiometer (R39).

Output switch (S2A, S2B) provides normal, reversed, or shorted output leads to the load. Short position is extremely useful when mechanically zeroing a galvanometer. In NORMAL position, the amplifier output is connected to pin H and common to pin F.

Section 5

Troubleshooting And Maintenance

Basic new design concepts in the Dana amplifier simplified circuit that minimizes the total number of components, eliminates mechanical choppers and their moving parts, and affords maximum reliability and long life through the exclusive use of silicon semiconductors.

5.1 TROUBLESHOOTING

The first step in troubleshooting the amplifier is to see if all inputs (power and signal) are present. Next is to check the DC supply voltages. The two series regulated supplies should provide plus and minus 20 volts (±2 volts) at about 10 millivolts peak-to-peak ripple.

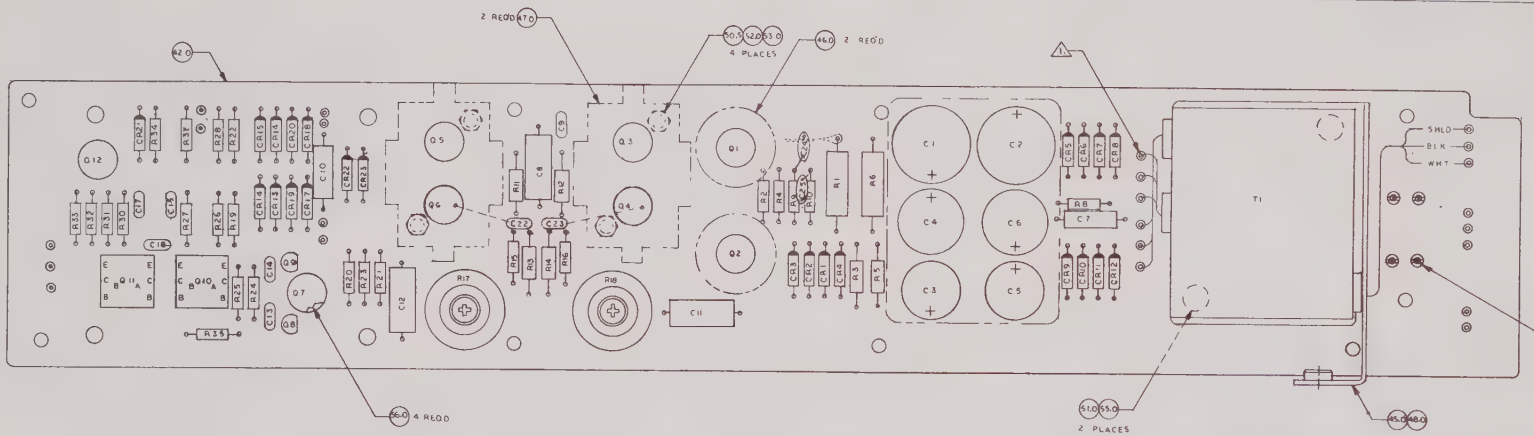
Because of the difficulty in signal tracing a closed loop amplifier (any error will appear throughout the loop) it is often more simple to troubleshoot with resistance measurements for each component (e.g., transistorsand diodes). If the user wishes to troubleshoot dynamically, he may break the loop by setting the gain switch to Z; adjusting the zero potentiometer (R39) to approximately 0 volts at the wiper, and jumpering point (N) to ground. By moving R38 from full cw to full ccw, the output should go through zero. Due to the high open loop gain, the output may appear noisy. By properly biasing each stage to the positive side and then to the negative side, the output should pass through zero. However, this should be done by experienced technicians as more damage may result if the transistors or diodes are overloaded.

Section 6

Drawings

	Part No.
Board Assembly — Model 2710	400476
Schematic - Model 2710	430267
Switch Assembly — Model 2710	400477
Board Assembly — Model 2720	400646
Schematic — Model 2720	430296
Switch Assembly — Model 2720	400647
Dimension Outline — 3000 Series (1) Enclosure	450907
Wiring Diagram - Connectors — Amplifier Enclosure	430273

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVED
A	REVISED PER E.O. #942	12-2-65	
B	REVISED PER E.O. # 1090	3-1-67	
C	ADD CROSS REF. CHART # DESIGNATORS, ADDED C24 & C25.	4-14-67	
D	REVISED PER E.O. 1124	7-17-67	
E	REVISED PER E.O. 1271	5-14-68	



CROSS REFERENCE CHART	
ITEM NO.	PART NO.
42.0	410169
45.0	450667
46.0	600016
47.0	600068
48.0	610111
49.0	610145
50.5	615015
51.0	615057
52.0	617002
53.0	617075
58.8	617079
56.0	920006

REF DES	B M ITEM	VALUE
R20	9	470Ω
R19	6	300Ω
R18	19	500Ω, CTS
R17	19	500Ω, CTS
R16	5	240Ω
R15	5	240Ω
R14	15	20Ω, 1/2W
R13	15	20Ω, 1/2W
R12	5	20Ω, 1/2W
R11	5	20Ω, 1/2W
R10	1	10Ω
R9	1	10Ω
R8	2	150Ω
R6	18	39Ω, 2W
R5	14	1.5K, 1/2W
R4	8	3.9K
R3	14	1.5K, 1/2W
R2	8	3.9K
R1	18	89Ω, 2W,

REF DES	B M ITEM	VALUE
C3	24	50UF 25V
C2	26	300UF 50V
C1	26	300UF 50V
R37	41	.5Ω
R35	13	75K
R34	17	8.45K ±1%
R33	16	59K ±1%
R32	16	59K ±1%
R31	10	5.6K
R30	7	36K
R28	3	160K
R27	4	20K
R26	7	36K
R25	10	5.6K
R24	12	6.2K
R23	11	56K
R22	6	300Ω
R21	9	470Ω

REF DES	B M ITEM	VALUE
Q5	38	005
Q23	31	009
Q1	33	005
C25	22	470 PF
C24	22	470 PF
C23	21.5	47PF
C22	21.5	47PF
C18	23	1150PF
C17	20	680PF
C15	21	.001UF
C14	20	680PF
C13	22	470 PF
C12	27	1UF, 25V
C11	27	1UF, 25V
C10	29	.0022 UF
C9	21	.001UF
C8	30	.022UF
C7	28	.015UF, 100V
C6	25	100UF 90V
C5	24	50UF 25V
C4	25	100UF 50V

REF DES	B M ITEM	VALUE
T1	38	AZTEC 1609
CR23	36	IN964 B
CR22	36	IN964 B
CR21	37	1 4N2AA210
CR20	34	504
CR3	34	504
CR2	35	IN 968 B
CR1	35	IN 968 B
Q12	33	005
Q11	32a	400483
Q10	32a	400483
Q9	32	T1415
Q8	32	T1415
Q7	31	009
Q6	33	005

NOTE: UNLESS OTHERWISE SPECIFIED, RESISTORS ARE 1/4W, ±5%.

T1 415 2N3565

VIEWED FROM CIRCUIT SIDE

QTY REQD	SYM	ITEM NO.	GOVT IDENT NO.	DANA PART NUMBER	NOMENCLATURE OR DESCRIPTION	SPECIFICATION

LIST OF MATERIALS OR PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON DECIMALS X ± .030 XX ± .020 XXX ± .010 ANGLES ± 0° 30'	DRAWN	J.E. SOLBERG	DANA LABORATORIES INC. IRVINE, CALIFORNIA
	CHECK		P.C. BOARD ASSY GALVO DRIVER, 2710
	ENGR		
	APPR		
MATERIAL	APPROVED		
FINISH	APPROVED		CODE IDENT NO. — SIZE D — 400476
			SCALE 2/1 — WEIGHT — SHEET —

400177			
NEXT ASSY	USED ON	NEXT ASSY	FINAL ASSY

APPLICATION	QTY REQD

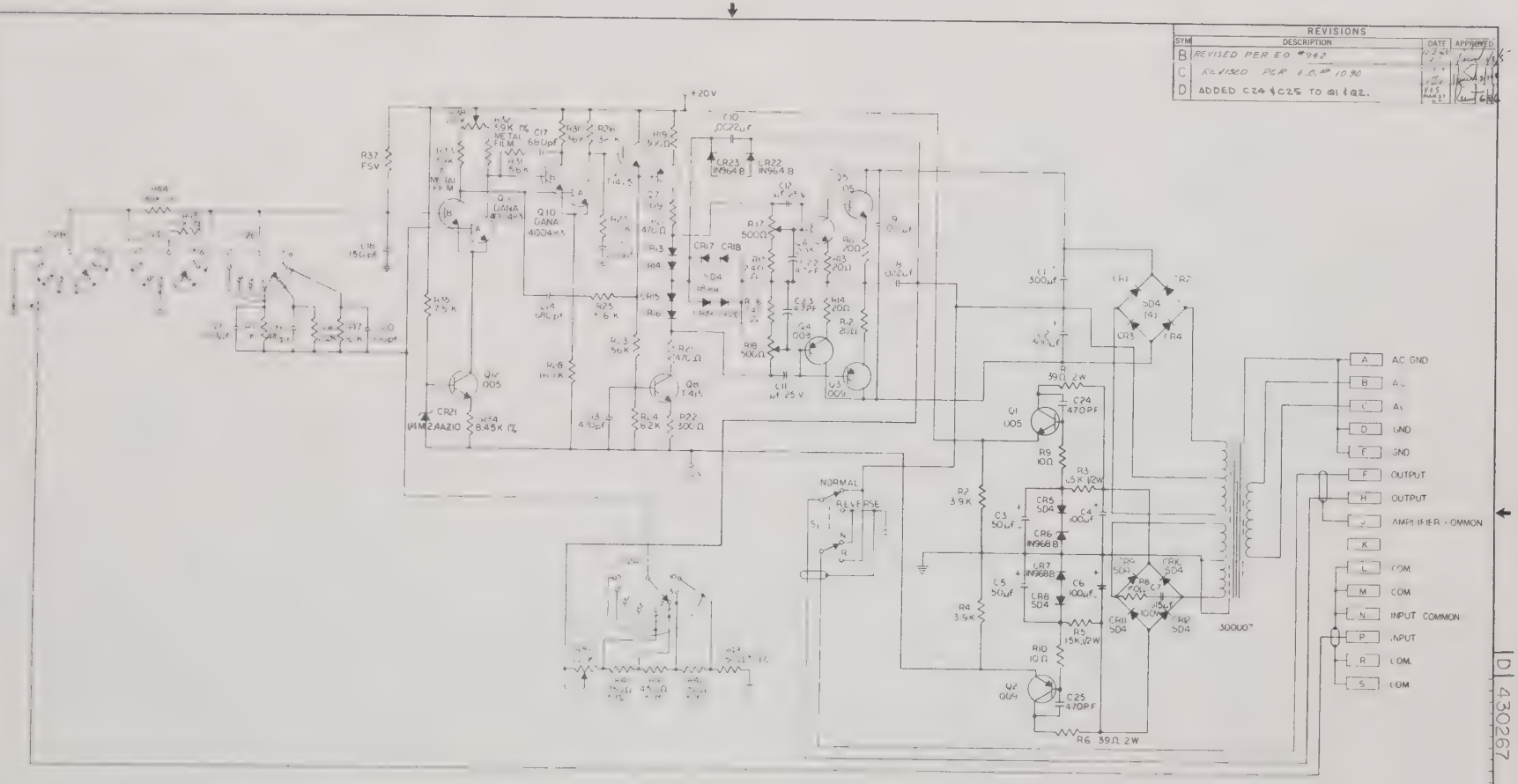
SYMBOLS
APPLICABLE TO DANA LABORATORIES INC. ONLY
SA — SUB-ASSY MRA — MAJOR REPL ASSY
MA — MODULE ASSY CA — COMPLETE ASSY

2. PAD INDICATED BY DOT LIES TO BASE LEAD OF TRANSISTOR. BASE LEADS ARE DETERMINED BY POSITION RELATIVE TO FLAT OF TRANSISTOR CASE.

1. SEE SCHEMATIC 430267.

NOTES UNLESS OTHERWISE SPECIFIED

400476



REVISIONS

SYM	DESCRIPTION	DATE	APPROVED
B	REVISED PER EO #942		
C	REVISED PER E.O. # 1090		
D	ADDED C24 & C25 TO Q1 & Q2.		

3 MISSING REFERENCE DESIGNATORS R29 R36 R44 R45 C16

2 HIGHEST REFERENCE DESIGNATORS- Q12 R47 C23 CR23

1 RESISTORS TO BE 1/8 W, ± 5%, CARBON

NOTES: UNLESS OTHERWISE SPECIFIED

QTY REQD	SYM	ITEM NO	GOVT IDENT NO.	DANA PART NUMBER	NOMENCLATURE OR DESCRIPTION	SPECIFICATION

LIST OF MATERIALS OR PARTS LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS X .010 XX ±.020 XXX ±.010
ANGLES ± 30'

MATERIAL

APPLICATION | QTY REQD

APPLIED
FIN SYS

DRAWN
CHECK
ENGR
APPR

APPROVED

APPROVED

DANA LABORATORIES INC
IRVINE, CALIFORNIA

SCHEMATIC
GALVO DRIVER, 2710

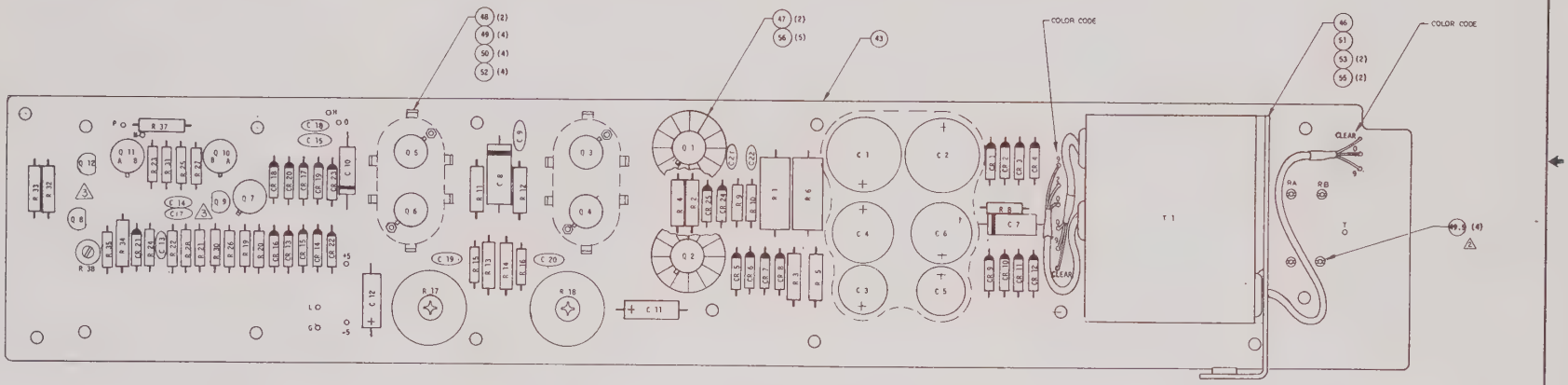
CODE IDENT NO. | SIZE D | 430267 | D

SCALE | WEIGHT | SHEET

ID 430267

REF DES	B/M ITEM	DESCRIPTION
C 14	21	330 pf
C 13	24.5	470 pf
C 12	28	1 MFD, 25 V
C 11	28	1 MFD, 25 V
C 10	31	.0015 MFD, 100 V
C 9	23	.001 MFD
C 8	30	.022 MFD, 100 V
C 7	29	.015 MFD, 100 V
C 6	26	100 MFD, 50 V
C 5	25	50 MFD, 25 V
C 4	26	100 MFD, 50 V
C 3	25	50 MFD, 25 V
C 2	27	300 MFD, 50 V
C 1	27	300 MFD, 50 V
CR 5	36	SD 4
CR 4		
CR 3		
CR 2		
CR 1	36	SD 4
C22	24.5	470PF
C21	24.5	470PF
C 20	24	47 pf
C 19	24	47 pf
C 18	22	100 pf
C17	21	330 PF
C 16		
C 15	23	.001 MFD
CR 19	36	SD 4
CR 18		
CR 17		
CR 16		
CR 15		
CR 14		
CR 13		
CR 12		
CR 11		
CR 10		
CR 9		
CR 8	36	SD 4
CR 7	37	1N968B
CR 6	37	1N968B
Q 5	34	D14
Q 4	32	009
Q 3	32	009
Q 2	32	445
Q 1	34	005
CR 25	39	1N752A
CR 24	39	1N752A
CR 23	38	1N968B
CR 22	38	1N968B
CR 21	40	1/4W 2.4AZ5
CR 20	36	SD 4
Q 12	33	415
Q 11	33	415
Q 10	354	016
Q 9	33	415
Q 8	33	415
Q 7	32	009
Q 6	24	014
R 4	15	1.6K, 1/2W
R 3	13	1.5K, 1/2W
R 2	15	1.6K, 1/2W
R 1	18	39 Ohm, 2 W
R 14	14	20 Ohm, 1/2 W
R 13	14	20 Ohm, 1/2W
R 12	14	20 Ohm, 1/2W
R 11	14	20 Ohm, 1/2W
R 10	1	10 Ohm
R 9	1	10 Ohm
R 8	3	150 Ohm
R 7		
R 6	18	39 Ohm, 2 W
R 5	13	1.5 K, 1/2W
R 18	19	500 Ohm POT
R 17	19	500 Ohm POT
R 16	6	240 Ohm
R 15	6	240 Ohm
R 32	16	59 K, 1 %
R 31	2	12 K
R 30	8	36 K
R 29		
R 28	4	160 K
R 27	5	20 K
R 26	8	36 K
R 25	2	12 K
R 24	11	6.2 K
R 23	10	56 K
R 22	7	300 Ohm
R 21	9	470 Ohm
R 20	9	470 Ohm
R 19	7	300 Ohm
T 1	41	P/N 300007
R 38	20	20 K POT
R 37	42	FSV
R 36		
R 35	12	7.5 K
R 34	17	8.45 K, 1%
R 33	16	59 K, 1 %

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	REVISED PER E.O. Nº 855	11-10-65	
B	" E.O. Nº 919	12-10-65	
C	REVISED PER E.O. Nº 1024	2-11-66	
D	ADDED NOTE 2; ADDED 49.5	3-7-66	
E	REVISED TO ADD C21 & C22	3-25-66	
F	REVISED PER E.O. # 1271	6-2-66	
H	REVISED PER E.O. Nº 1355	7-6-66	



T-415 2N3565

VIEWED FROM CIRCUIT SIDE

SCALE 4/1

CROSS REFERENCE CHART	
ITEM NO	PART NO
43	410179 A
46	450867
47	600016
48	600068
49	610067
50	610084
51	610111
52	611627
53	615057
55	617079
56	970006
49.5	610145

⚠ PAD INDICATED BY DOT TIES TO BASE LEAD OF TRANSISTOR, BASE LEADS ARE DETERMINED BY POSITION RELATIVE TO FLAT OF TRANSISTOR CASE.

2. INSTALL ITEM 49.5 PRIOR TO COMPONENT ASSY.

1. ALL RESISTORS ARE 1/4 W, ± 5%, CARBON.

NOTES: UNLESS OTHERWISE SPECIFIED

QTY REQD	SYM	ITEM NO.	GOV'T OR VENDOR NO.	DANA PART NUMBER	NOMENCLATURE OR DESCRIPTION	CODE IDENT	SPECIFICATION

LIST OF MATERIAL OR PARTS LIST

MATERIAL —

APPLIED FINISH —

HEAT TREATMENT —

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON DECIMALS: .X ± .030; .XX ± .020; .XXX ± .010
ANGLES ± 0° 30'
FORMED ANGLES ± 1.0°
ECCENTRICITY BETWEEN DIA ON THE SAME AXIS SHALL NOT EXCEED .010 TIR.
INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS MIL D 1000 AND MIL D 70327

CONTRACT NO.

	NAME	DATE
DR	Finch	3 SEPT 65
CHK	Nelson	9 Dec 65
APPD		12/15

R&S 4-11-66

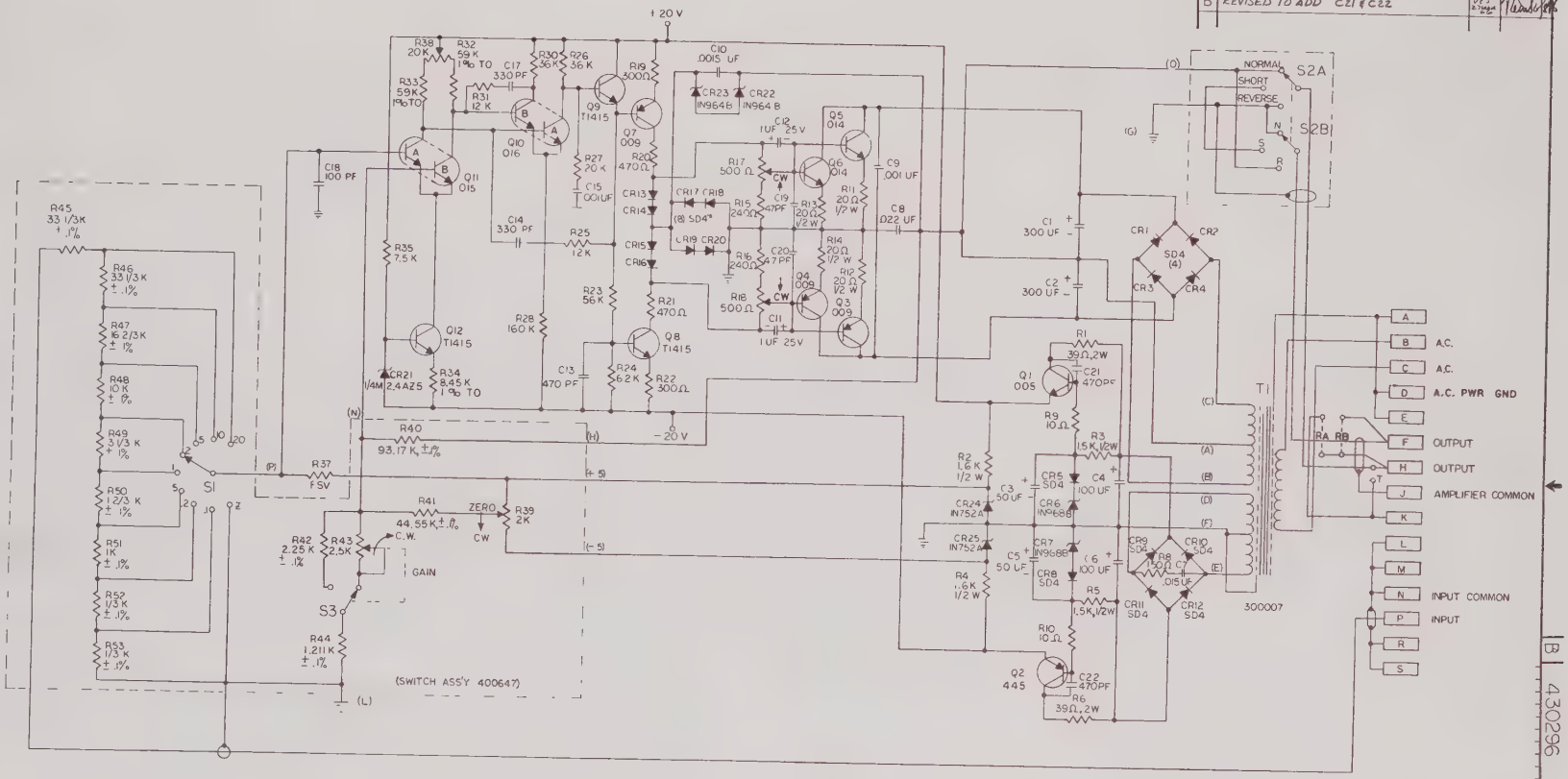
DRWG 351838

DANA LABORATORIES INC.
IRVINE, CALIFORNIA

P.C. BOARD ASSY — 2720

SIZE	CODE IDENT NO.	DWG NO.	
D		400646	H

SCALE 2/1 WT SHEET 1 OF 1



REVISIONS			
SYM	DESCRIPTION	DATE	APPROVED
A	REVISED PER EO NO. 855		
B	REVISED TO ADD C21 & C22		

LAST REF DES	DES NOT USED
R53	C16
CR25	R7
Q2?	R29
Q12	R36
S3	

400646	2720	REF	REF
NEXT ASSY	USED ON	NEXT ASSY-FINAL ASSY	
APPLICATION		QTY REQD	

SYMBOLS
APPLICABLE TO DANA LABORATORIES INC. ONLY
SA—SUB—ASSY MRA—MAJOR REPL ASSY
MA MODULE ASSY LA—COMPLETE ASSY

QTY REQD	SYM	ITEM NO.	GOVT IDENT NO.	DANA PART NUMBER	NOMENCLATURE OR DESCRIPTION	SPECIFICATION

LIST OF MATERIALS OR PARTS LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON DECIMALS X ± .030 XX ± .020 XXX ± .010
ANGLES ± 0° 30'

MATERIAL
APPLIED FINISH

DRAWN W. Edie 16 Aug 1962
CHECK
ENGR
APPR
APPROVED
APPROVED

DANA LABORATORIES INC.
IRVINE, CALIFORNIA

SCHEMATIC - 2720

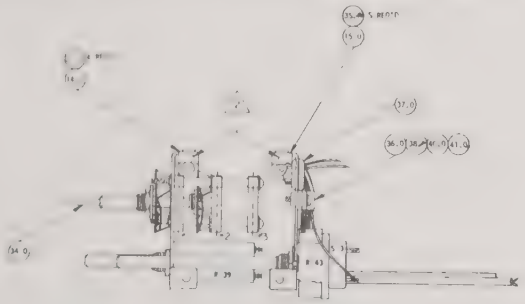
CODE IDENT NO. —
SIZE D
430296
B
SCALE —
WEIGHT —
SHEET 1 OF 1

B 430296

2. LETTERS & NUMBERS IN PARENTHESES IDENTIFY BOARD CONTACTS FOR INTERCONNECTING WIRING.
L RESISTORS TO BE 1/4 W, ± 5% CARBON.

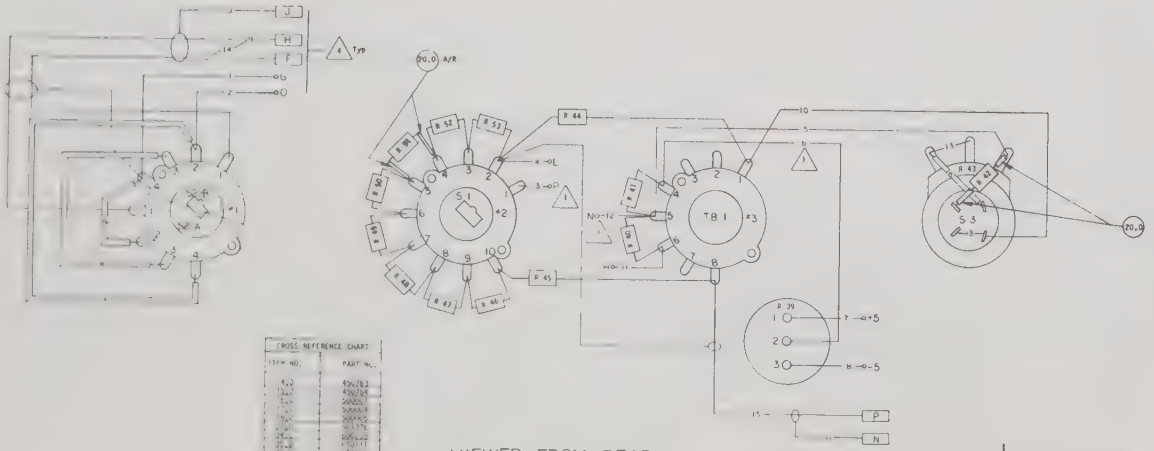
NOTES: UNLESS OTHERWISE SPECIFIED

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	REVISED PER E.O. # 941		



REF DES	B/M ITEM	DESCRIPTION
TB 1 S 1 S 2 S 3	34.0	Switch-Rotary
R 53	3.0	1/3 K .1%
R 52	3.0	1/3 K .1%
R 51	2.0	1 K .1%
P 50	5.0	1 2/3 K .1%
R 49	6.0	3 1/3 K .1%
R 48	1.0	10 K .1%
R 47	7.0	16 2/3 K .1%
R 46	8.0	33 1/3 K .1%
R 45	8.0	33 1/3 K .1%
R 44	4.0	1,211 K .1%
R 43	13.0	POT 2.5 K & Switch
R 42	13.0	2.25 K .1%
R 41	9.0	44.55 K .1%
R 40	10.0	93.17 K .1%
R 39	12.0	POT 2 K, 10 Turn

WIRE COLOR CHART		
WIRE NO.	COLOR	ITEM NO.
0	BLACK	22.0
1	WHT-BRN-GRN	23.0
2	WHT-BRN-RED	24.0
3	WHT-BRN-ORG	25.0
4	WHT-BRN-YEL	26.0
5	WHT-BRN-GRN	27.0
6	WHT-BRN-BLU	28.0
7	WHT-BRN-VIO	29.0
8	WHT-BRN-GRY	30.0
9	WHITE	----
10	WHT-RED-BLU	31.0
11	WHT-RED-RED	32.0
12	WHT-RED-ORG	33.0
13	BUSS WIRE	17.0
14	TWST SHLD PR	19.0
15	RG 174/U	21.0
16	SLVD BUSS WIRE	17.0 &20.0



VIEWED FROM REAR

CROSS REFERENCE CHART	
ITEM NO.	PART NO.
4.0	450782
5.0	450783
6.0	200004
7.0	200005
8.0	200006
9.0	450784
10.0	450785
11.0	450786
12.0	450787
13.0	450788
14.0	450789
15.0	450790
16.0	450791
17.0	817027
18.0	817102

NOTES: UNLESS OTHERWISE SPECIFIED

4 Letter indicates(o) eyelets and B, E connector fingers identified on P. C. Board.

Dress shielded wire with shrinkable tubing (Item 16.0) at switch only.

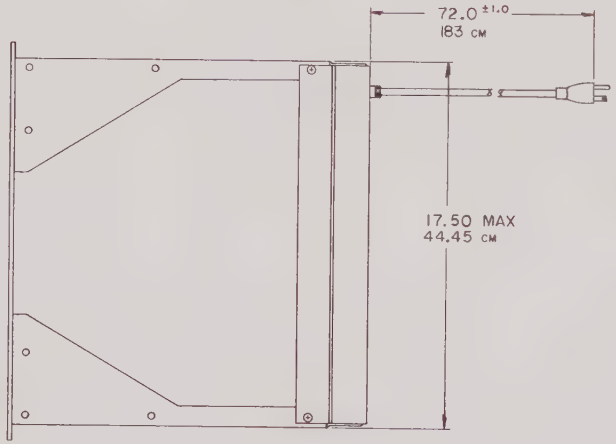
No press nut on top tab rotation (both brackets)

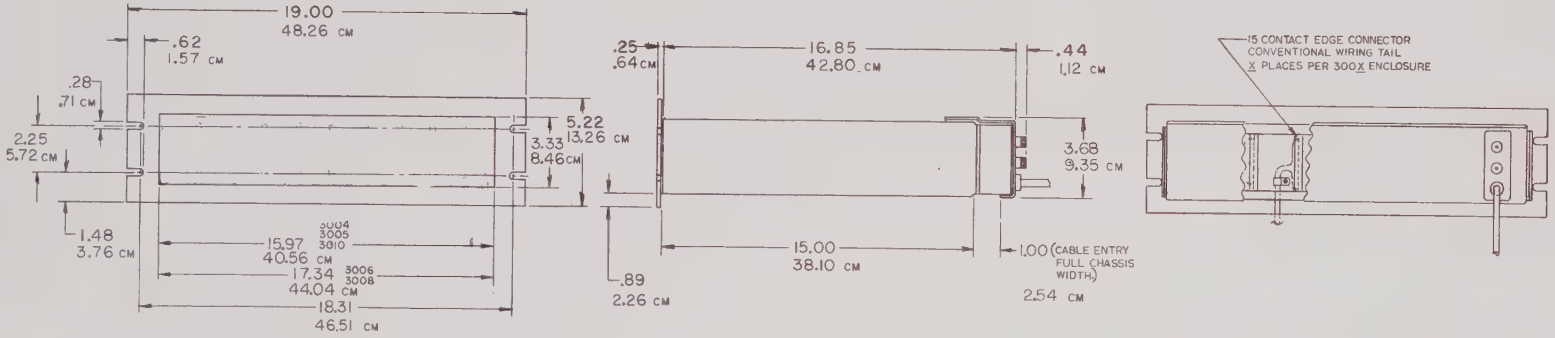
QTY REQD	SYM	ITEM NO.	GOVT OR VENDOR NO.	DANA PART NUMBER	NOMENCLATURE OR DESCRIPTION	CODE IDENT	SPECIFICATION

LIST OF MATERIAL OR PARTS LIST

MATERIAL	UNLESS OTHERWISE SPECIFIED	CONTRACT NO.	DANA LABORATORIES INC. IRVINE, CALIFORNIA
APPLIED FINISH	DIMENSIONS ARE IN INCHES. TOLERANCES UN: DECIMALS / ANGLES; .X ± .030 / ± 0° 30'; .XX ± .020; .XXX ± .010; FORMED ANGLES ± 1 0°	NAME / DATE: DR 11-17-65; CHK 11-19-65; APPD 11/19/65	SWITCH ASSY – 2720
HEAT TREATMENT	ECCENTRICITY BETWEEN DIA ON THE SAME AXIS SHALL NOT EXCEED .010 TIR. INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS M., D 1000 AND MIL D 70127		SIZE D; CODE IDENT NO; DWG NO 400647; SCALE; WT; SHEET 1 OF 1

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVED





QTY REQD	SYM	ITEM NO.	GOV'T IDENT NO.	DANA PART NUMBER	NOMENCLATURE OR DESCRIPTION	SPECIFICATION
LIST OF MATERIALS OR PARTS LIST						

NEXT ASSY	USED ON	NEXT ASSY FINAL ASSY
APPLICATION		QTY REQD

SYMBOLS
APPLICABLE TO DANA LABORATORIES INC. ONLY
SA—SUB-ASSY MRA—MAJOR REPL. ASSY
MA—MODULE ASSY CA—COMPLETE ASSY

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS X ± .030, XX ± .020, XXX ± .010
ANGLES ± 0° 30'

MATERIAL

APPLIED FINISH

DRAWN	L. Dorsey	10/4/65
CHECK	D. Finch	10/4/65
ENGR		
APPR		
APPROVED		
APPROVED		

DANA LABORATORIES INC.
IRVINE, CALIFORNIA

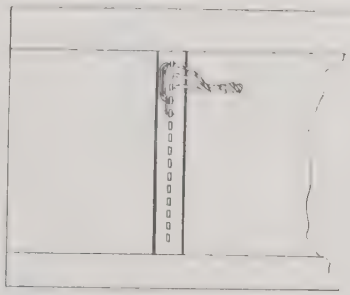
DIMENSION OUTLINE—
3000 SERIES
(-1) ENCLOSURE

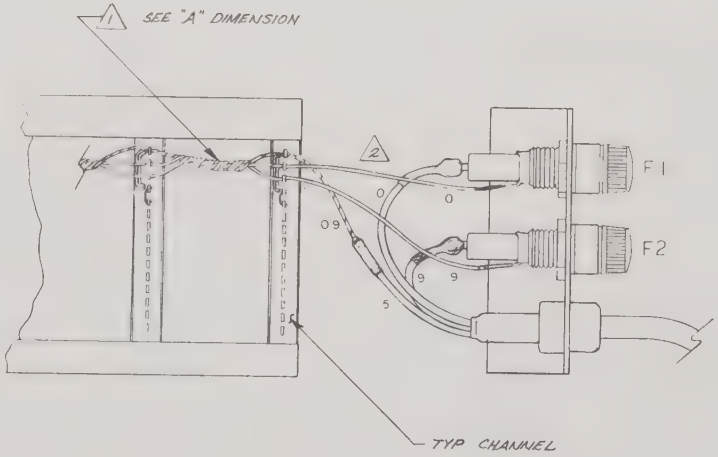
CODE IDENT NO	SIZE	
	D	450907
SCALE NONE	WEIGHT	SHEET 1 OF 1

NOTES

450907

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVED





"A" DIMENSION

CHANNEL	ENCLOSURE	"A" DIM
4 CHANNELS	3004-1	5.0 ±.10
5 CHANNELS	3005-1	5.0 ±.10
6 CHANNELS	3006-1	4.5 ±.10
8 CHANNELS	3008-1	3.8 ±.10
10 CHANNELS	3010-1	4.0 ±.10

1 [illegible] 3 IN

2 "A" DIMENSION REFERS ONLY TO THE LENGTH OF WIRE

NOTES: UNLESS OTHERWISE SPECIFIED

NEXT ASSY	USED ON	NEXT ASSY	FINAL ASSY
APPLICATION		QTY REQD	

SYMBOLS
APPLICABLE TO DANA LABORATORIES INC. ONLY
SA — SUB ASSY MRA — MAJOR REPL ASSY
MA — MODULE ASSY CA — COMPLETE ASSY

QTY REQD	SYM	ITEM NO.	GOV'T IDENT NO.	DANA PART NUMBER	NOMENCLATURE OR DESCRIPTION	SPECIFICATION

LIST OF MATERIALS OR PARTS LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS: X ± .030, XX ± .020, XXX ± .010
ANGLES ± 0° 30'

MATERIAL

APPLIED FINISH

DRAWN T HANSSEN 5-6-65
CHECK
ENGR
APPR

APPROVED

APPROVED

DANA LABORATORIES INC.
IRVINE, CALIFORNIA

WIRING DIAGRAM - CONNECTORS AMP'L ENCLOSURE

CODE IDENT NO	SIZE	
	C	430273-274 -275-276-277

SCALE — WEIGHT SHEET 1 OF 1

430273-74-75-76-77

168-00 LIETZ 1030 TOPPY LIGHT 4-64

DANA LABORATORIES
Repair/Return Form

DANA MODEL NO. _____ SERIAL NO. _____

RETURNED ASS'Y. P/N _____ SERIAL NO. _____

PROPERTY OF _____

RETURN TO _____

DESCRIPTION OF TROUBLE _____

OPERATING CONDITIONS (ie: Environment, Source Z) _____

SIGNED _____ DATE _____

(USE BACK OF FORM IF NECESSARY)

REPAIR INFORMATION

(TO BE COMPLETED BY REPAIR FACILITY)

SYMPTOMS NOTED _____

ACTUAL CAUSE _____

REPAIRS REQUIRED _____

SIGNED _____ DATE _____

RETURN TO USER FILE

5M 10-65

Warranty

It is the practice of Dana Laboratories, Incorporated, to manufacture only products of a quality that will merit customer satisfaction. The company recognizes that customer satisfaction is achieved, not only by delivering products meeting advertised performance specifications and having a high level of reliability, but also by honestly and efficiently fulfilling their warranty obligations as set forth below.

Dana Laboratories, Inc., agrees to correct, either by repair or replacement, any defect of material or workmanship in Dana-manufactured units or components which develop within one year after delivery of the equipment to the original purchaser — provided that the equipment has been subjected only to normal and proper use.

In the event of failure of any component delivered with Dana equipment, but not manufactured by Dana Laboratories, assistance will be given the customer in obtaining, from the original manufacturer, reasonable adjustment under that manufacturer's warranty.

Any item claimed to be defective during the warranty period must be returned to Dana Laboratories, Inc., with transportation charges prepaid. The item will be repaired and returned to the purchaser with return transportation prepaid by Dana unless, of course, the item is found not to be defective or found to be damaged by misuse — in which case it will be returned to the purchaser with repair and transportation billed collect.

DANA

M

MP MASTER
MA31090